

## NPTEL

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#### Courses » Estimation for Wireless Communications – MIMO/OFDM Cellular and Sensor Networks



Announcements

Course

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# Unit 5 - Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, Properties of L Estimate, Examples – Mullti-Antenna Downlink and MIMO Channel Estimation





# Course outline

How to Access the Portal?

Week 1 - Basics of Estimation, Maximum Likelihood (ML)

Week 2 - Vector Estimation

Week 3 - Cramer-Rao Bound (CRB), Vector Parameter Estimation, Multi-Antenna Downlink Mobile Channel Estimation

Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, Properties of LS Estimate, Examples – Mullti-Antenna Downlink and MIMO Channel Estimation

- Lecture 16 Least Squares
   Solution
   Maximum
   Likelihood ML
   Estimate
   Pseudo Inverse
- Lecture 17 Properties of
  Least Squares
  Estimate Mean

# **Assignment-4**

The due date for submitting this assignment has passed. Due on 2017-08-20, 23:59 IST. As per our records you have not submitted this assignment.

1) Consider the maximum likelihood (ML) multi-antenna channel estimation **1 point** problem with N transmitted pilot vectors  $\mathbf{x}(k) = [x_1(k), x_2(k), \dots, x_M(k)]^T$ ,  $1 \le k \le N$  and N received symbols  $y(1), y(2), \dots, y(N)$ . Let the channel vector be  $\mathbf{h} = [h_1, h_2, \dots, h_M]^T$ . Let the pilot matrix be  $\mathbf{X}$ . The ML estimate of  $\mathbf{h}$  is,

$$(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{y}$$

$$(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{h}$$

$$\mathbf{y}^{-1}\mathbf{y}$$

$$\mathbf{X}^{-1}\mathbf{y}$$

$$(\mathbf{X}\mathbf{X}^T)^{-1}\mathbf{X}^T\mathbf{y}$$

No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

$$(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{y}$$

2) Consider a multi-antenna channel estimation scenario with N=4 pilot vectors **1 point**  $\mathbf{x}(1) = [3,2]^T, \mathbf{x}(2) = [-2,1]^T, \mathbf{x}(3) = [-1,-2]^T, \mathbf{x}(4) = [-1,3]^T$ . Let the corresponding received vector be  $\mathbf{y} = [3,2,2,1]^T$ . Let the dB noise variance be -4.77dB. The corresponding pilot matrix  $\mathbf{X}$  is,



Covariance and Distribution

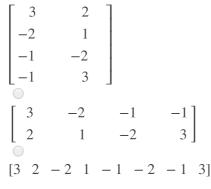
- O Lecture 18 -Least Squares Multi Antenna Downlink Maximum Likelihood Channel Estimation
- O Lecture 19 -Multiple Input Multiple Output MIMO Channel Estimation -Least Squares Maximum Likelihood ML
- O Lecture 20 -Example -Least Squares Multiple Input Multiple Output MIMO Channel Estimation
- OQuiz: Assignment-4
- Assignment-4 Solution

Week 5 - Inter Symbol Interference. Channel Equalization, **Zero-forcing** equalizer, **Approximation** error of equalizer

Week 6 -Introduction to Orthogonal Frequency Division Multiplexing (OFDM) and Pilot **Based OFDM** Channel Estimation, Example

Week 7 - OFDM -**Comb Type Pilot** (CTP) Transmission, Channel **Estimation in** Time/ Frequency Domain, CTP Example, Frequency Domain Equalization (FDE), Example-**FDE** 

Week 8 -**Sequential Least** Squares (SLS) Estimation -





No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

$$\begin{bmatrix} 3 & 2 \\ -2 & 1 \\ -1 & -2 \\ -1 & 3 \end{bmatrix}$$





3) Consider a multi-antenna channel estimation scenario with N=4 pilot vectors 1 point  $\mathbf{x}(1) = [3, 2]^T, \mathbf{x}(2) = [-2, 1]^T, \mathbf{x}(3) = [-1, -2]^T, \mathbf{x}(4) = [-1, 3]^T$ . Let the corresponding received vector be  $\mathbf{y} = [3, 2, 2, 1]^T$ . Let the dB noise variance be -4.77dB. The pseudo-inverse of the pilot matrix **X** is,

$$\frac{1}{87} \begin{bmatrix}
16 & -13 & -4 & -9 \\
7 & 7 & -9 & 16
\end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix}
-11 & 17 & 14 & 21 \\
5 & -27 & 9 & 12
\end{bmatrix}$$

$$\begin{bmatrix}
42 & 32 \\
-29 & 16 \\
-21 & -72 \\
-16 & 38
\end{bmatrix}$$

$$\begin{bmatrix}
1 & 33 & -23 & 8 & 25
\end{bmatrix}$$

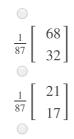
No, the answer is incorrect.

**Accepted Answers:** 

Score: 0

$$\frac{1}{87} \begin{bmatrix} 16 & -13 & -4 & -9 \\ 7 & 7 & -9 & 16 \end{bmatrix}$$

4) Consider a multi-antenna channel estimation scenario with N=4 pilot vectors **1** point  $\mathbf{x}(1) = [3, 2]^T, \mathbf{x}(2) = [-2, 1]^T, \mathbf{x}(3) = [-1, -2]^T, \mathbf{x}(4) = [-1, 3]^T$ . Let the corresponding received vector be  $\mathbf{y} = [3, 2, 2, 1]^T$ . Let the dB noise variance be -4.77dB. The estimate of the channel vector **h** is,



Scalar/ Vector Cases. Applications -Wireless Fading Channel Estimation, SLS Example

$$\frac{1}{87} \begin{bmatrix} -12 \\ 45 \end{bmatrix}$$

$$\frac{1}{87}\begin{bmatrix} 5 \\ 33 \end{bmatrix}$$

No, the answer is incorrect.

#### Score: 0

### **Accepted Answers:**





5) Consider a multi-antenna channel estimation scenario with N=4pilot vectors  $\mathbf{x}(1) = [3, 2]^T, \mathbf{x}(2) = [-2, 1]^T, \mathbf{x}(3) = [-1, -2]^T, \mathbf{x}(4) = [-1, 3]^T$ Let the corresponding received vector be  $\mathbf{y} = [3, 2, 2, 1]^T$ . Let the dB noise variance be -4.77dB. The covariance of the ML estimate is,



No, the answer is incorrect.

#### Score: 0

#### **Accepted Answers:**

$$\frac{1}{261} \begin{bmatrix} 6 & -1 \\ -1 & 5 \end{bmatrix}$$

- 6) Consider a multi-antenna channel estimation scenario. In general, when are the 1 point estimation errors of the various channel coefficients uncorrelated for a scenario with IID noise samples of variance  $\sigma^2$  each?
  - When the pilot matrix is square
  - When the pilot matrix is invertible
  - When the columns of pilot matrix are orthogonal
  - None of the above

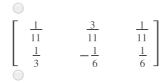
#### No, the answer is incorrect.

#### Score: 0

#### **Accepted Answers:**

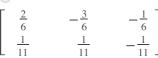
When the columns of pilot matrix are orthogonal

7) Consider a multi-antenna channel estimation scenario with N=3 pilot vectors 1 point  $\mathbf{x}(1) = [1, 2]^T, \mathbf{x}(2) = [3, -1]^T, \mathbf{x}(3) = [1, 1]^T$ . Let the corresponding received vector be  $\mathbf{y} = [2, 1, 2]^T$ . The pseudo-inverse of the pilot matrix  $\mathbf{X}$  is,



$$\begin{bmatrix} 1 & 3 & 1 \\ 2 & -1 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \frac{2}{11} & -\frac{3}{11} & -\frac{1}{11} \\ \frac{1}{3} & \frac{1}{6} & -\frac{1}{6} \end{bmatrix}$$





No, the answer is incorrect.

Score: 0

## Accepted Answers:

$$\begin{bmatrix} \frac{1}{11} & \frac{3}{11} & \frac{1}{11} \\ \frac{1}{3} & -\frac{1}{6} & \frac{1}{6} \end{bmatrix}$$





8) Consider a multi-antenna channel estimation scenario with N=3 pilot vectors 1 pt  $\mathbf{x}(1) = [1,2]^T, \mathbf{x}(2) = [3,-1]^T, \mathbf{x}(3) = [1,1]^T$ . Let the corresponding received vector be  $\mathbf{y} = [2,1,2]^T$ . The ML estimate of the channel is given as

$$\begin{bmatrix} \frac{7}{11} \\ \frac{5}{6} \\ \end{bmatrix}$$

$$\begin{bmatrix} \frac{6}{11} \\ \frac{1}{6} \\ \end{bmatrix}$$

$$\begin{bmatrix} \frac{5}{6} \\ \frac{1}{11} \\ \end{bmatrix}$$

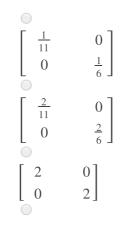
No, the answer is incorrect.

Score: 0

#### **Accepted Answers:**

$$\begin{bmatrix} \frac{7}{11} \\ \frac{5}{6} \end{bmatrix}$$

9) Consider a multi-antenna channel estimation scenario with N=3 pilot vectors **1 point**  $\mathbf{x}(1) = [1,2]^T, \mathbf{x}(2) = [3,-1]^T, \mathbf{x}(3) = [1,1]^T$ . Let the corresponding received vector be  $\mathbf{y} = [2,1,2]^T$ . Let the dB noise variance be 3dB. The covariance of the ML estimate is,



No, the answer is incorrect.

Score: 0

**Accepted Answers:** 



10 Consider a multi-antenna channel estimation scenario with N=3 pilot vectors 1 point  $\mathbf{x}(1) = [1, 2]^T, \mathbf{x}(2) = [3, -1]^T, \mathbf{x}(3) = [1, 1]^T$ . The correlation between the estimation errors of the individual channel coefficients is,











No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

0

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